

A 10-kg object dropped from a certain window strikes the ground in 2.0 s. Neglecting air resistance, a 5-kg object dropped from the same window strikes the ground in

A. 1.0 s. B. 2.0 s. C. 4.0 s. D. 8.0 s.

A ball thrown upward reaches its maximum height, and then falls back. If air resistance is negligible, its acceleration is:

A. less on the way up than on the way down.
B. less on the way down than on the way up.
C. the same up and down but zero at the top.
D. the same at all points in the motion.

A man standing on a bridge throws a stone horizontally with a speed of 20 m/s. The stone hits the water below 3 s later.

The bridge is

- A. 45 m high. B. 60 m high.
C. 30 m high. D. 20 m high.

Torque

- A torque (or leverage) is a force which tends to make an extended object rotate
- If a force is applied to an object, the line connecting the center of the rotation to the site where the force is applied is called the lever arm
- If a force is perpendicular to the lever arm, the torque is given by

$$\tau = FL$$



Torque in Everyday Life: Torque Wrench

The torque wrench is a special wrench with a built-in indicator that shows you how much torque (force to rotate) you're applying to a bolt.

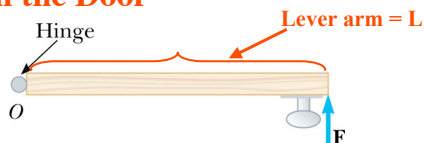


Torque in Everyday Life (II)

- Consider the force required to open the door. Is it **easier to open** the door by **pushing/pulling away from the hinge** or **close** to the hinge?
- The further away from the hinges you push on a door, the more torque you are applying, and the easier it is to open.
- Torque is the tendency of a force to rotate an object about some axis



Torque on the Door



- Lever arm is the perpendicular distance from the axis of rotation to the line of action of the applied force
- If the force is applied away from the hinge, the lever arm is larger and it corresponds to a larger Torque.

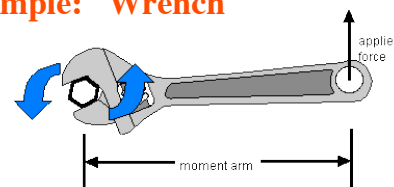
$$\text{Torque} = \text{Force} \times \text{Lever Arm}$$

In symbols:

$$\tau = FL$$

Units	
•SI	•Newton meter (Nm)
•US Customary	•Foot pound (ft lb)

Torque Example: Wrench



- When you tighten the bolt with a wrench, you are exerting a torque on the bolt.
- If the torque you exert is greater than the counter torque of the friction in the bolt, the bolt will rotate (tighten).
- Like for forces, if all torques are equal, you will be unable to tighten the bolt.

Torque Equilibrium

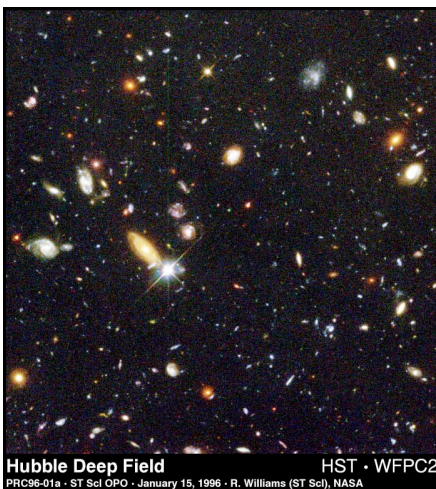
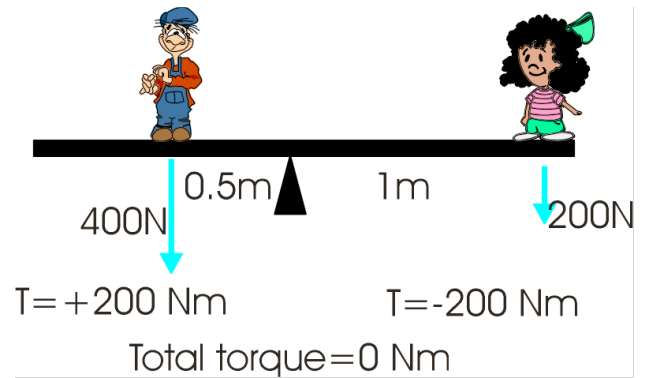
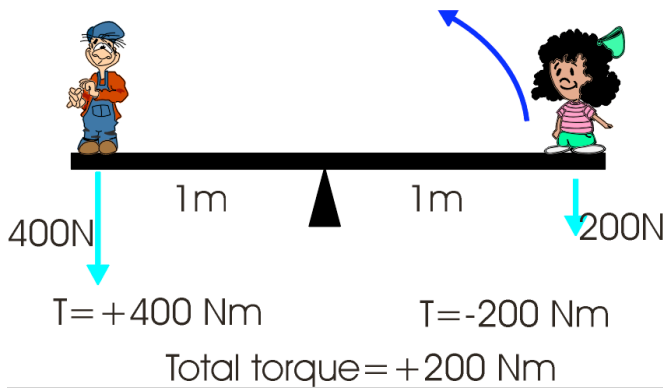
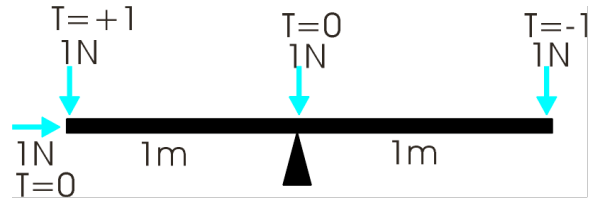
- Torque is the rotational counterpart of force:
 - a net torque changes an object's rotational motion.
- An object is in equilibrium when:
 - the net torque or total torque is zero

$$\tau_{\text{net}} = \tau_{\text{total}} = FL = 0$$

- Since torques can have opposing effects we assign a sign to torques, for example:

➤ **Positive torque** if produces a counterclockwise rotation

➤ **Negative torque** if produces a clockwise rotation



Universe

The Universe is made of matter and energy:

- Matter is the substance, it is the stuff we can see, smell, feel. It has mass and occupies space
- Energy is the mover of the substance. It is abstract and it is only evident when it changes.

Energy

- Things have energy if they are able to do work. A human body has energy; so does a tank of gas and a falling stone.
- Energy is the **capacity to do work**.
- Energy exists in a variety of forms: Chemical Energy, Potential Energy, Nuclear Energy, Thermal (Heat) Energy etc...

Work

- Work is done whenever energy is changed from one form into another.
- The amount of energy changed from one form to another is known as the energy transferred:

work done = energy transferred

Work

- Work is done by a force on an object if the force acts on the object in it moves through a distance **parallel** to the force.

Work = Force times Distance moved

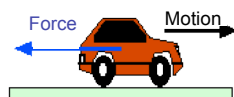
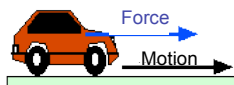
$$W = F d$$

- The unit for work is the Joule (J) which is equivalent to Newton meter

$$1 \text{ J} = 1 \text{ N m} = 1 \text{ Kg m}^2 / \text{s}^2$$

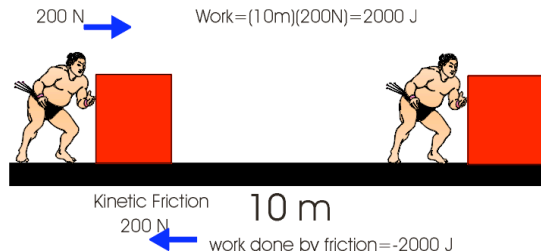
Work

- Positive Work when force and motion are in the same direction
- Negative Work when force and motion are in opposite direction



Examples of Work

- Let us say that Paul pushes a box across the floor at a constant velocity by exerting a force of 200N.
- He pushes the box a distance of 10 m

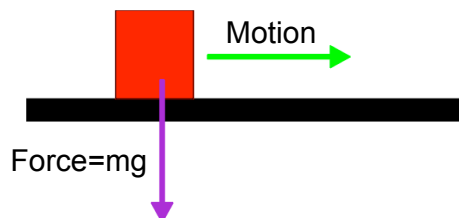


Examples of Work (cont.)

- The work Paul does on the box is
 - $W = (200 \text{ N})(10 \text{ m}) = 2000 \text{ J}$
- Since the box is not accelerating we know that the force of static friction, working against the motion of the box, is -200 N .
- The force of friction does negative work, works against the motion of the box.
- The work done by friction is
 - $W = (-200 \text{ N})(10 \text{ m}) = -2000 \text{ J}$

Work=0 Example

- The weight of this brick, which is sliding across a horizontal table, does no work since the weight is perpendicular to the motion



Kinetic Energy

- The amount of work that is required to accelerate an object from rest to a velocity v is $mv^2/2$
- This work can subsequently be done by that object on some other object down the road
- This potential to do work stored in a moving object is called **kinetic energy**

Power

- Power is equal to the amount of work done per unit time.

$$\text{Power} = \frac{\text{work done}}{\text{time interval}}$$

- The **unit for power** in Standard Units is the **Watt (W)** which is equivalent to Joule/second

$$1 \text{ W} = 1 \text{ J} / \text{s}$$

Another unit for power is horsepower (hp)

$$1 \text{ hp} = 746 \text{ W}$$